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THE TWO SCHOOLS OF PLANT PHYSIOLOGY AS AT PRESENT EXISTING IN GERMANY AND ENGLAND.

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(Continued from p. 217.)

The nature of the experiments will be best understood by a brief statement of the outlines of his theory in regard to the processes by which the water is carried up. He regards the ducts, and to a certain extent, the tracheids, as reservoirs into which the water is passed from the absorbing cells. These ducts, except it may be in a certain period of the year when the so-called root pressure is taking place, are never filled with water but with alternating columns of air and water. All who are at all familiar with this subject will remember that this was the first argument against the new theory. How could the water pass up in the cell lumena when these were not themselves filled? It is claimed now that this very fact is the one which admits of such a possibility. That is, these alternating columns make a combination known as the Jaminschen chain, from the name of the Frenchman, Jamin, who was the first to compute the force exerted by a chain of air and water columns in a capillary tube. Such an apparatus was called by his name, and the discovery of such a system of chains in the ducts and tracheids of woody tissue has been the strong point in the new water theories. The manner of action of this chain may be seen at once, the meniscuses acting as

forces to prevent the motion of the water which would otherwise sink. In other words, the sole function of the chain is to prevent the water from yielding to the action of the gravity. In this way according to the distribution and tension of the air bubbles, the water is more or less evenly distributed throughout the whole stem of the tree and is ready for use whenever needed at different altitudes. The next step in the problem is to discover the factor by which the water is drawn out and set in motion upward. It is here that Professor Schwendener differs from nearly all the younger men who adhere even too zealously to his cause. In short, the last set of experiments which he made were for the purpose of disproving the claims of those who consider themselves able to follow all the successive forces which act in sending the water upward from the root hairs to the transpiring leaves. The question of lumen versus wall was not at all touched by these experiments. On the other hand, they were made to test the length of alternating air and water columns, diameter of tube, etc., and from these results a series of mathematical computations was made, it is true from data more or less uncertain, but yet with such allowances for extreme cases as to prove conclusively that some other force was necessary than those held sufficient by his contemporaries.

Pieces of wood were taken from the inner portions of the trunks of various trees, with apparatus allowing perfectly air tight processes. The pieces were transposed from the tube of the borer into glycerine or water from which all air had been expelled. From these computations it was shown that in no case would it be possible for the action of suction caused by the evaporation from the leaves to reach down much below the crown of the tree, and in case of trees with trunks from 50 to 100 metres long this might be considered proof against the possibility of the force reaching downward until it reaches that effected below by the forces acting in the lower part of the tree. The whole labor is merely to disprove certain theories, not to establish new ones.

In conclusion Professor Schwendener says the results agree with those expressed in 1867. Stated briefly it may be said

they prove that some other forces must be present besides those recognized by authors who claim to give an explanation of the mechanical forces acting in forcing the water upward. These forces must lie more or less scattered through the length of the trunk because they are concentrated at points at considerable distances from each other, and tensions arise which are not present. The Jaminish chain serves to hold the water in the ducts and tracheids from falling by its own weight; the living cells of the medullary rays and of the wood parenchym, in some manner as yet unknown to us, take the water held in these reservoirs and distribute it to places where it is needed.

Now contrast this with the explanation of Sachs, which is virtually the same as that held by all claiming that the wall is the chief path taken by the water in its ascent. This may be stated as follows: Water is able to reach the tops of the trees fast enough to supply the lack caused by transpiration, owing to the peculiar quality residing in the micellæ of the lignified cellulose, which enables the water molecules to move with great rapidity, when the equilbrium is once disturbed by transpiration above. This peculiar quality is entirely lost when once the water has dried out of the walls so the micellæ touch each other. Imbibition may occur as in ordinary cases but the micellæ have lost that character which enabled the water particles to move with such rapidity. One of the favorite experiments given in favor of this theory is that of Th. Hartig with the stick, which being held upright and a drop of water placed on its upper surface, it at once disappears and a drop of water appears below. Now it is admitted that this succeeds only when the wood of the stick is saturated with water. Schwendener's explanation of this phenomenon is extremely simple and takes away all evidence of the rapidly moving particles or molecules of water in the wall. In this saturated condition, there would be continuous water columns inside the tracheids, the cut surface at the top transpires enough to form the concave meniscuses for all these columns, the added drop is sufficient to destroy these meniscuses, the water columns sink until the drop is drawn in and new menis-

cuses again form, preventing farther sinking. In case the wood is partly dried, instead of a drop appearing below, the water at the top sinks in without farther visible result either at once or slowly. In this case there are no continuous water streams as before, they are broken by internal meniscuses forming the chain.

Contrast now the methods of reasoning used in the two cases. It is admitted on both sides that all the mechanical forces here in play whose action we understand, are not sufficient to cause the water to ascend higher than about 30 feet. Sachs, therefore, affirms the presence of a quality in the micellæ of the wood, which if it existed there would account for the water rising. There is no other proof that this quality exists than simply this fact. This statement, perhaps, should be modified by adding, there is no proof which is considered conclusive.

On the other hand, the theory as taught by Schwendener stops short of the assumption of a mechanical cause. No known mechanical forces can be found active here which are sufficient to explain the result. As there is always one factor of whose manner of action we are ignorant, namely: the action of living matter, he assumes this to be the factor which accomplishes that part of the result not reached by mechanical causes. This inference is supported by the arrangement of the living cells in connection with the ducts and tracheids holding the water. For example the presence of wood parenchym around those ducts which are otherwise not in connection with the medullary rays.

In regard to the experiment of Hartig before referred to, it may be of interest to those not familiar with the anatomy of the tissues through which the water passes if a few words of added explanation are given. In the saturated piece of wood we have said there were continuous water columns in the tracheids, these are continuous only in the sense of there being no air columns present. These tracheids are closed cells, therefore there is the interruption of the cell walls at intervals in the otherwise continuous columns. So that according to Schwendener's view all that is proven by the drop of water

experiment is, the amount of resistance of filtration. This in a piece of wood ten metres long in an upright position is less than one atmosphere. Similar experiments have been tried, the stick being placed obliquely; from these it has been proven that a column of water 12 centimetres in height is able to move a water net 100 centimetres or one metre in length.

Now if we turn from the discussion of this old and long disputed question to one of the most recent and perhaps least known, namely: "Turgor as the necessary condition of growth" we shall find the same principle again, only illustrated in a different way.

A cell is said to be be turgescent when the hydrostatic pressure within exceeds that of the atmosphere without. The common teaching regarding the manner of growth of cell wall in surface is, that the cell must be in the turgescent state, that is that the actual growth depends upon and is the result of such condition of cell wall. Owing to the pressure within, the micellæ of the wall are supposed to be separated from each other until the extreme limit of elasticity is reached. In this way place is made for the new particles of matter between the old.

This theory is known in botanical literature as the Sachs-De Vries theory as it was first suggested by Sachs and afterward supported by De Vries. It is often referred to as the one sustained by Naegeli, but a careful study of his works shows that what he says upon this subject has reference to tissue tensions for the most part, rather than to simple turgor.

It is now claimed by Schwendener that there is no proof whatever that the surface growth of the wall depends upon turgor, and on the contrary, that there is considerable evidence against this assumption. For example, it has been shown that cells having an excess of turgor, are not growing at all, while cells are found in a state of great activity whose turgor is very small. One and one-half atmosphere is considered about the medium for ordinary turgescent cells.

Again, in a certain kind of tissue found in stems of water plants and others where large air spaces occur, growth of wall

takes place in direct opposition to a turgor force, that is, the wall grows inward into a cell which is strongly turgescent.

There is also one other ground for the position taken by Schwendener's school in reference to the relation of turgor to growth. This is certain facts connected with what is known as "Gliding growth," "Gleitendes Wachsthum." The principle included in this idea may be briefly explained as follows:

In the early stages of the secondary growth, during the time when the new cells are receiving or taking on their final character as vessels and libriform cells, etc., a growth takes place by means of the walls of one cell gliding along the wall of another. To explain this, it must be assumed that the walls of the young cell consist of two lamellæ; whether this is so from the beginning or not is entirely unknown, but at the stage of the development where the gliding growth begins, the two layers are there. These are not to be distinuguished by the highest power of the microscope, the wall appearing perfectly homogeneous under the most powerful lens. The subsequent growth is such as to prove that there are two lamellæ, as under no other assumption could such growth be possible.

This assumption has also other and positive facts sustaining it, besides the negative one mentioned above. In certain cases the thin young walls of cambium cells have been proven by maceration to consist of two or more lamellæ.

Now according to this principle there must reside in certain growing cells some force entirely independent of the mere mechanical one of pressure. In other words, there is an active as well as passive condition of growth and this active condition depends on certain properties of living matter and these properties are entirely outside and independent of what we know as mechanical force. Again we are brought to the same conclusion as before, there is a force residing in living matter of whose manner of action we are ignorant. That this force exists in this matter we have certain and positive proof.

This subject of turgor as before stated is one of the most recent questions and in a certain sense less important than the standard ones concerning the phenomena of growth.

To treat any one of the latter class fully would require more time than the limits of this paper allow. It is however, in these questions that the peculiar character of the new school is best expressed. The preference given to mechanical questions is evident from the list of subjects previously given as representing the line of physiological teaching Schwendener follows with his present classes. It is in connection with such questions that he has acquired his present reputation, and he is known best through the discussions of mechanical theories which are either peculiarly his own, or in which he opposes those of other leading physiologists.

But it by no means follows from this that he recognizes the mechanical forces as the only ones acting in the plant economy, nor that in his treatment of these, he fails to group their relations to the whole in a way to injure the unity of the entire subject. Rather than this it may be said he gives the first place to such questions because be believes this logical order of all investigation.

If the present aim of the scientist be to trace all the processes of living matter back to the action of chemical and physical forces, how can this result be reached unless we begin with the study of those laws whose action we know and understand?

It is in this sense that he says we are yet far from being able to take up the subtle and delicate questions connected with the action of living matter. There are many problems whose solutions lie nearer to us, and on these solutions depend our ability to handle the more remote and difficult questions of plant physiology.

One single illustration of what is here claimed may be found in what he says of the expression "Mechanics of Growth." Of this he says, "There is no such thing as the mechanics of growth, for it is the immediate result of the action of living matter and of this action we are ignorant."

In answer to a possible criticism as to there being but two main sources of the principles of plant physiology as they are now taught in Germany and England it may be said: there is

no question regarding the position occupied by Schwendener as leading the modern school in Germany.

In reference to the influence of Sachs on the leading text books of the present day, this is even more evident. While many other men of eminence in this field have contributed the results of their labors, not only by original research but also by writing text books, it is as yet true that they differ but little in methods of work or in the results obtained, from those general methods and principles which were first disseminated from the laboratory of Würzburg from the pen of the most popular and brilliant writer the world has yet produced in this special field of investigation.

In conclusion, therefore, it remains only to contrast once more, briefly the leading features of both schools.

In the one there is a tendency to put mere speculation and fanciful conjecture in the place of theory. Rather than to admit our present ignorance and weakness, effects are sometimes referred to causes which cannot be proven in harmony with those laws of nature which are recognized in other departments of natural science.

In the other the principal lines of research are in the direction of mechanical questions, but at the same time there is a clear and distinct recognition of our present limitations and of the relative value of such questions in the ultimate determination of the action of forces which are yet beyond our reach.

To the botanists of the present day and the future it remains to verify and reject, choosing the true and rejecting the false from both lines of research, till the decisions of the future shall make clear how much of error yet clings to the old school and the new.